

CHAPTER 1

INTRODUCTION

1-1. Purpose. This manual provides guidance and engineering procedures for the design of breakwaters and jetties.

1-2. Applicability. This manual applies to all HQUSACE/OCE elements and field operating activities (FOA) having responsibility for the design of civil works projects.

1-3. References. In addition to the design guidance presented herein, additional information on specific subjects can be obtained from the following manuals and special report:

- a. ER 1110-2-100
- b. ER 1110-2-8151
- c. ER 1165-2-304
- d. EM 1110-1-1804
- e. EM 1110-1-2101
- f. EM 1110-2-1607
- g. EM 1110-2-1612
- h. EM 1110-2-1614
- i. EM 1110-2-1615
- j. EM 1110-1-1802
- k. EM 1110-2-1901
- l. EM 1110-2-1902
- m. EM 1110-2-1903
- n. EM 1110-2-1904
- o. EM 1110-2-2000
- p. EM 1110-2-2502
- q. EM 1110-2-2906

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r. EM 1110-2-3300

s. EM 1110-2-5025

t. CEGS 02362

u. CEGS 02366

v. Coastal Engineering Research Center, CE, 1983, "Construction Materials For Coastal Structures," Special Report No. 10, U.S. Army Engineer Waterways Experiment Station, P.O. Box 631, Vicksburg, MS 39180

w. Coastal Engineering Research Center, CE, 1984, "Shore Protection Manual," Vols I and II, U.S. Army Engineer Waterways Experiment Station, P.O. Box 631, Vicksburg, MS 39180. Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402

1-4. Bibliography. Item numbers are used throughout this manual to indicate bibliographic references. In publications where authors are not listed the organization and the date of publication are given. These publications are listed in alphabetical order in Appendix A and are available for loan upon request to the Technical Information Center (TIC) Library, US Army Engineer Waterways Experiment Station (WES), PO Box 631, Vicksburg, Mississippi 39180-0631.

1-5. Background. The Corps of Engineers is responsible for over 600 breakwaters and jetties, many of which date to the mid and late 1800's. A summary of their locations and types is presented in Appendix D. Originally, the design and the construction of breakwaters and coastal protection structures were based on trial and error resulting from man's conflicts with nature. Later, existing experience was the guiding hand and it was not until the 1930's that model tests were introduced to aid in the design of such structures. Today, model tests are commonly used and play a significant role in the design of sophisticated coastal structures.

1-6. Inventory. An inventory of WES breakwater stability studies is given in Appendix B.

1-7. Symbols. For convenience, symbols and unusual abbreviations used in this manual are listed and defined in the Notation (Appendix C).

1-8. General. This manual presents factors that influence the location of breakwaters and jetties, the determination of the type and magnitude of forces to which the structures will be subjected, the selection of construction materials, and the choice of structure types that best suit a particular location. Even though design methodologies are based on the latest state-of-the-art developments, they are not intended to replace individual engineering initiative. Departures from the manual which are in accordance with sound engineering principles and judgment are acceptable for unusual situations;

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however, to prevent misunderstanding between the designer and reviewer those departures should be explained and supported. This manual presents guidance for the design of breakwaters and jetties; however, the guidance herein is applicable to other coastal structures that are subjected to similar forces. Typical examples of various types of existing breakwaters and jetties and the experience gained from their performance are included within this manual.

1-9. Definitions. The following definitions and distinctions are offered for the sake of clarity:

a. Breakwater. A breakwater is a structure employed to reflect and/or dissipate the energy of water waves and thus prevent or reduce wave action in an area it is desired to protect. Breakwaters for navigation purposes are constructed to create sufficiently calm waters in a harbor area, thereby providing protection for the safe mooring, operating, and handling of ships and protection of shipping facilities. Breakwaters are sometimes constructed within large, established harbors to protect shipping and small craft in an area that would be exposed to wave action excessive for the purpose. Offshore breakwaters may serve as aids to navigation or shore protection or as both, and differ from other breakwaters in that they are generally parallel to and not connected with the shore.

b. Jetty. A jetty is a structure, generally built perpendicular to the shore, extending into a body of water to direct and confine a stream or tidal flow to a selected channel and to prevent or reduce shoaling of that channel. Jetties at the entrance to a bay or a river also serve to protect the entrance channel from storm waves and crosscurrents, and when located at inlets through barrier beaches jetties also serve to stabilize the inlet location.

c. Stone and Rock. Stone is defined as a construction material; that is, rock which has been removed from its natural position. Rock is defined as a naturally formed consolidated mineral matter in its natural geological position.

1-10. Types of Breakwaters and Jetties.

a. Rubble-Mound. Rubble-mound structures are typically constructed with a core of quarry-run stone, sand, or slag, and protected from wave action by one or more stone underlayers and a cover layer composed of stone or specially shaped concrete armor units. The structures are suitable for nearly all types of foundations and any economically acceptable water depth. A proposed structure may necessarily be designed for either nonbreaking or breaking waves, depending upon positioning of the breakwater and severity of anticipated wave action during its economic life. Some local wave conditions may be of such magnitude that the protective cover layer must consist of specially shaped concrete armor units in order to provide economic construction of a stable breakwater. Most local design requirements are advantageously met by stone armor. Figure 1-1 shows a typical rubble-mound section. The design of rubble-mound structures is discussed in Chapter 4.

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SEASIDE

LEESIDE

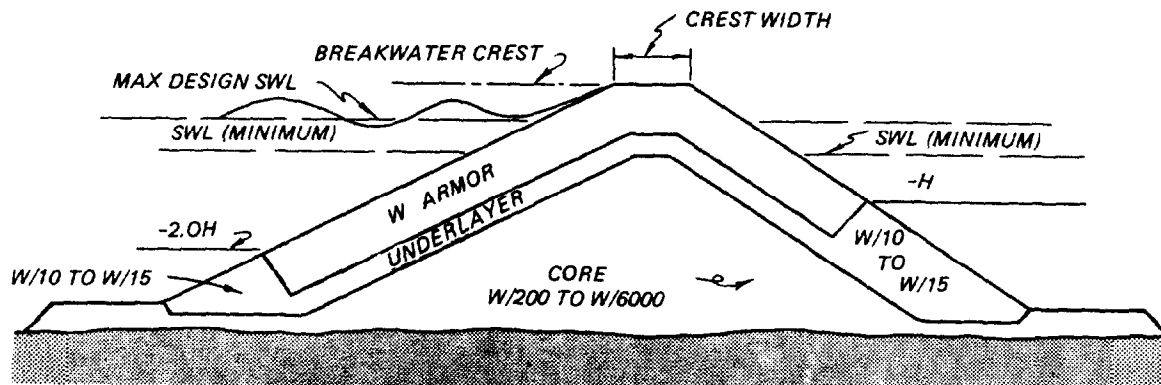


Figure 1-1. Typical rubble-mound section for seaside wave exposure

b. Sheet Piling. Timber sheet piling, held in position by round timber piles and usually protected at the base by stone riprap, has been used where storm waves are mild. Timber used in salt water where marine borers are present should be treated to avoid premature deterioration of the structure; timber pile structures are also subject to sand and ice abrasion. Steel and concrete sheet piling are also used; compared with timber structures, steel and concrete generally have higher initial costs and lower maintenance costs. Figures 1-2 through 1-4 present examples of timber, concrete, and steel structures, respectively. The design of sheet pile structures is discussed in Chapter 5.

c. Floating. Any structure which has a composite unit weight less than the water in which the structure is placed and is primarily used to reduce wave heights can be categorized into this group. Typically, floating structures are only effective for relatively short wave periods. Some advantages include portability, low cost, insensitivity to water depth, and possible enhancement of marine life. These structures can be box, pontoon, tethered float, or a variety of other types. Examples of the most commonly used types are shown in figure 1-5. Design of pontoon and tethered-float scrap tire breakwaters is described in Chapter 6.

d. Miscellaneous. Other types of structures that do not fit into the previous categories are as follows:

(1) Crib. Structures of this type are built of timber or precast concrete members, and some of the compartments of the crib are floored. The timber cribs are floated into position and settled upon a prepared foundation by filling the floored compartments with stone. The unfloored compartments are then filled with stone to give stability. The structure is capped with

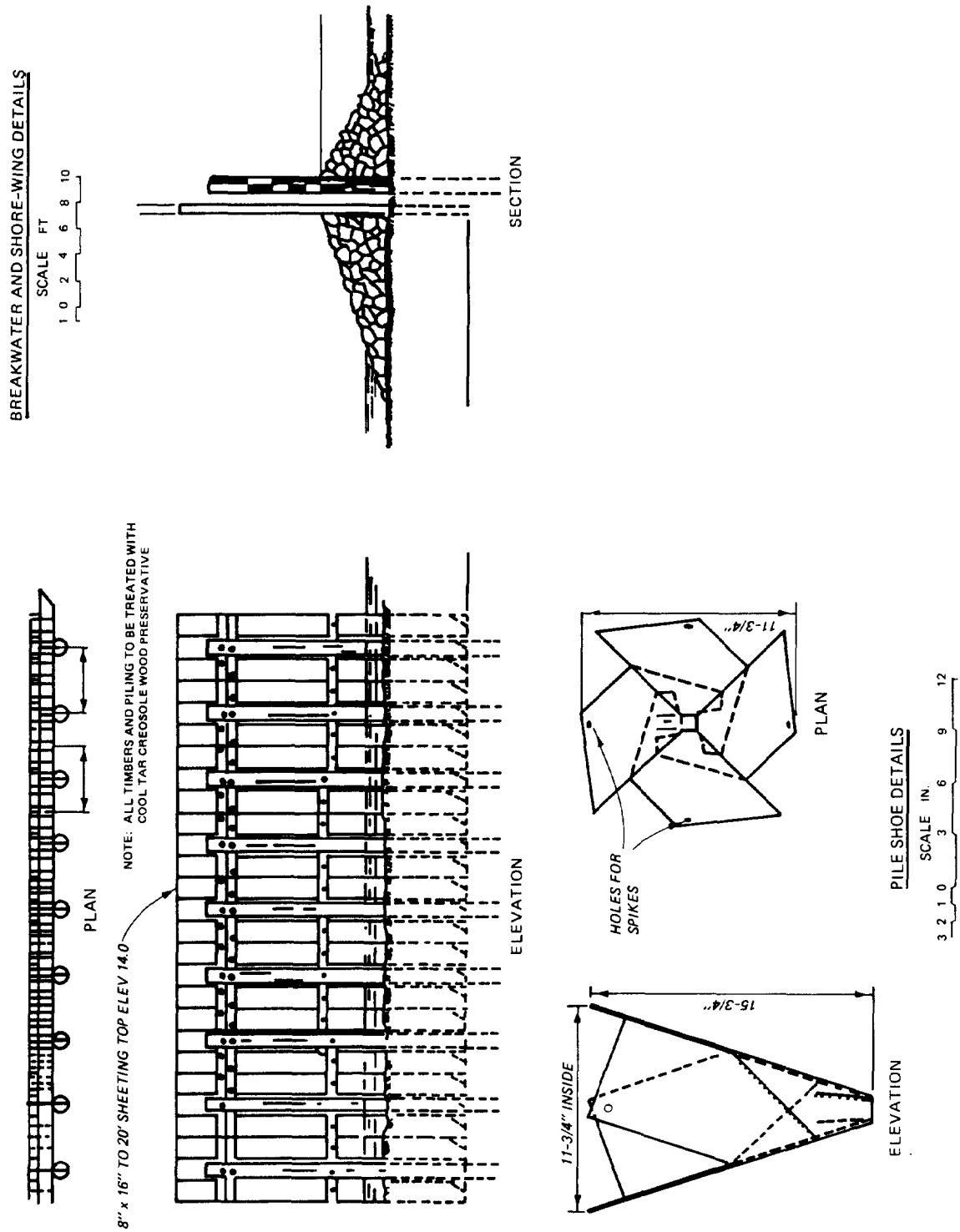
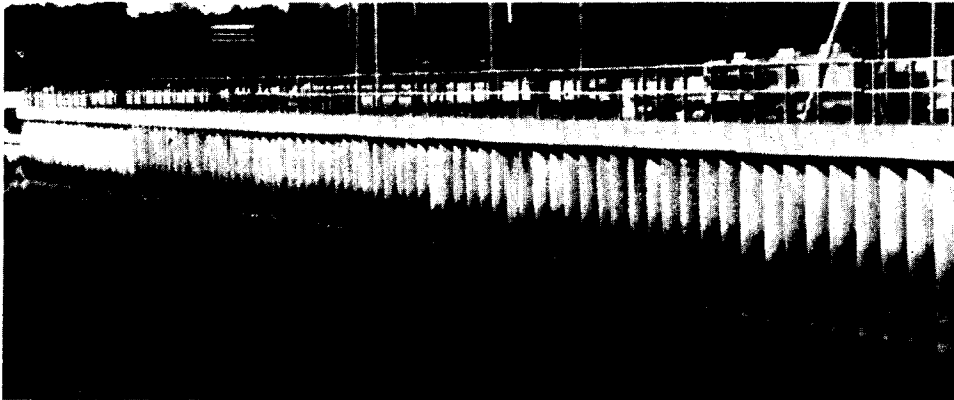
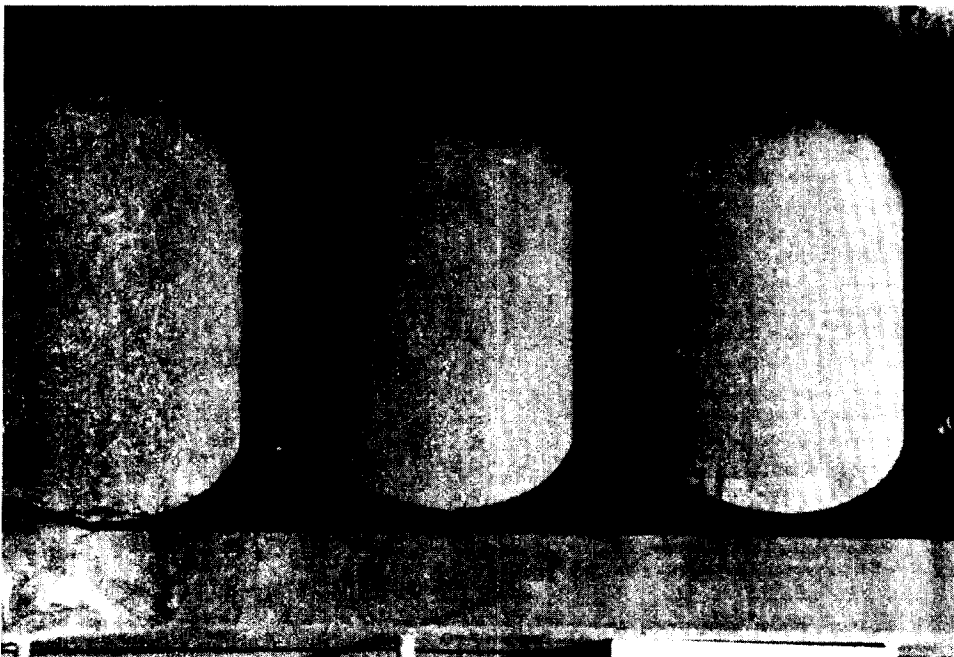


Figure 1-2. Timber sheet pile breakwater constructed at Yaquina Bay and Harbor, Oregon



a. General view



b. Close-up

Figure 1-3. Concrete breakwater constructed at
Pass Christian, Mississippi

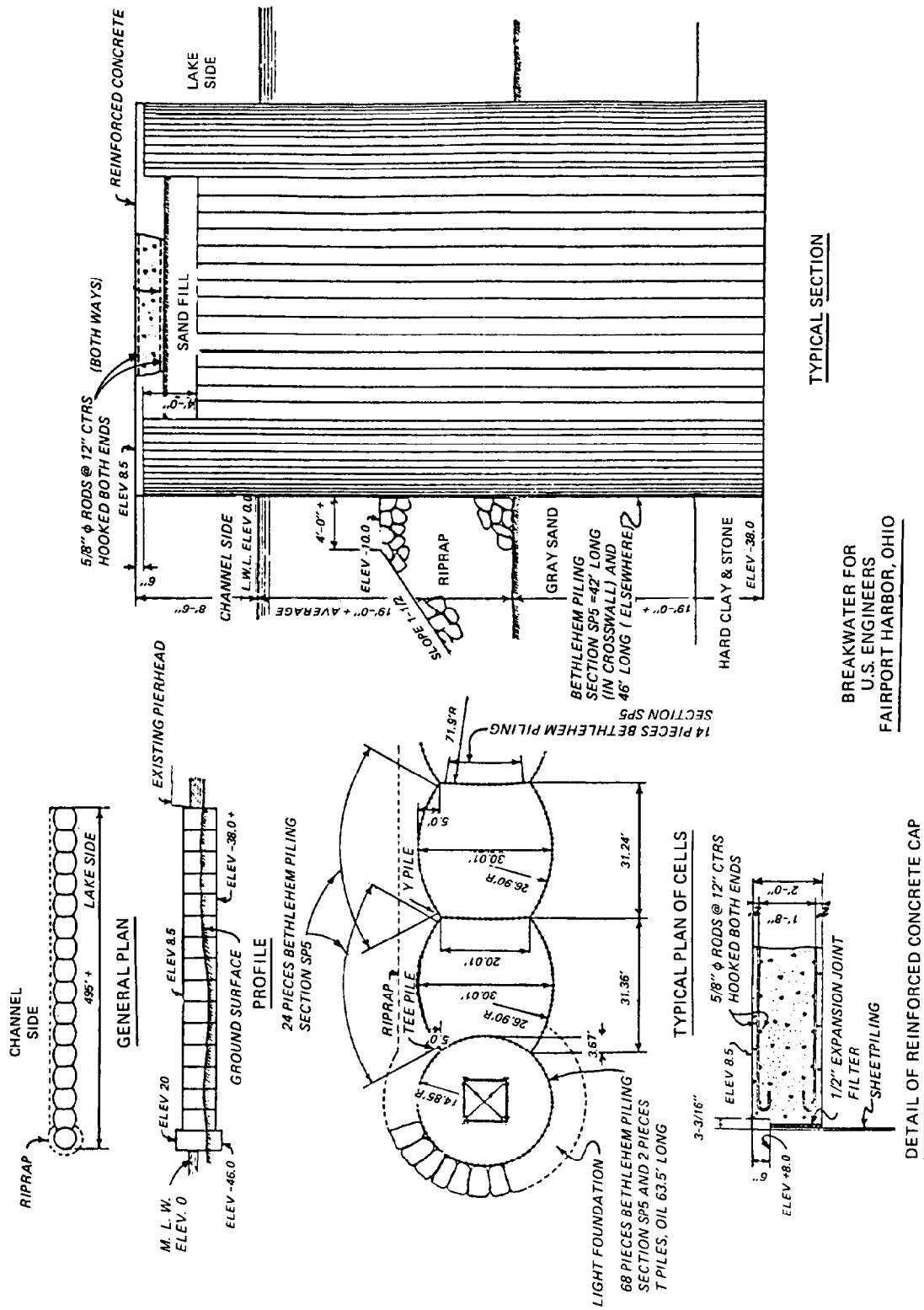


Figure 1-4. Steel sheet pile breakwater constructed at Fairport Harbor, Ohio

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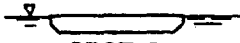
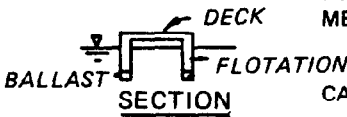
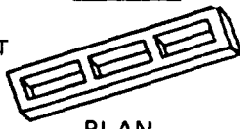

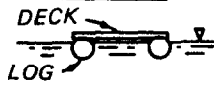


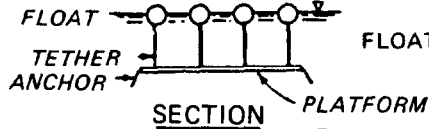
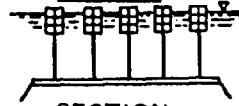


TYPE	VIEW	REMARKS
BOX SOLID RECTANGLE		REINFORCED CONCRETE UNITS ARE THE MOST COMMON TYPE.
BARGE	 SECTION	STANDARD BARGE SIZES ON INLAND WATERWAYS ARE 195' x 35' x 12' AND 175' x 26' x 11'. INCLINED BARGES (ONE END SUBMERGED) HAVE BEEN TESTED.
PONTOON TWIN PONTOON	 SECTION	CATAMARAN SHAPE
OPEN COMPARTMENT	 PLAN	ALSO CALLED ALASKA TYPE
A FRAME	 SECTION	
TWIN LOG	 SECTION	DECK IS OPEN WOOD FRAME.
MAT TIRE MAT	 SECTION	SCRAP TIRES STRUNG ON POLE FRAMEWORK OR BOUND TOGETHER WITH CHAIN OR BELTING. FOAM FLOTATION IS USUALLY NEEDED
LOG MAT	 PLAN	LOG RAFT CHAINED OR CABLED TOGETHER.
TETHERED FLOAT	 SECTION	
SPHERE	 SECTION	FLOATS PLACED IN ROWS.
TIRE	 SECTION	ARRANGEMENT SIMILAR TO SPHERES. STEEL DRUMS WITH BALLASTS CAN BE USED IN LIEU OF TIRES.
SLOPING FLOAT	 SECTION	

Figure 1-5. Types of floating breakwaters

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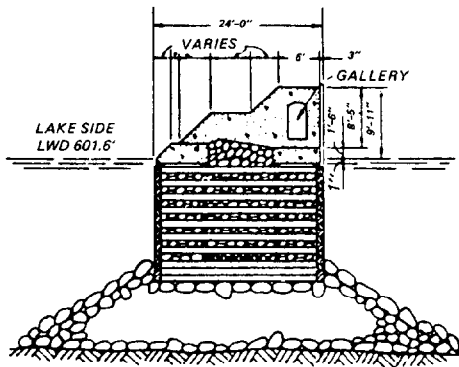
timber, concrete, or capstones. Stone-filled timber cribs can withstand considerable settlement and racking without rupture. The superstructure and decking of cribs set on a rubble-mound foundation are often constructed of timber to allow for settlement of the crib. Timber used in this construction in salt water must be treated for protection against the marine borer. When decay of the timber makes replacement of the superstructure necessary, concrete can be used since the structure will probably have settled into a permanent position by that time. An example of a timber crib breakwater is shown in figure 1-6.

(2) Composite. Monolithic walls placed on underwater rubble mounds are referred to as composite breakwaters in this manual. The rubble mound is generally used either as a foundation for the wall or as a main substructure surmounted by a wall superstructure with a vertical or inclined face. It is often used where the foundation is soft and subject to scour. The foundation is usually prepared by placing layers of rubble until adequate bearing pressure is obtained for the complete structure. Figure 1-7 shows examples of typical composite jetty sections.

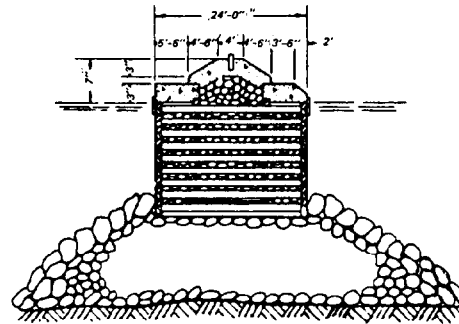
(3) Concrete caisson. Caisson construction is sometimes used whereby reinforced concrete shells are floated into position, settled upon a prepared foundation, filled with stone or sand to give stability, and then capped with concrete slabs or capstones. Such breakwaters can be constructed with parapet walls. Concrete caissons are generally of two types: one type has a bottom of reinforced concrete which is an integral part of the caisson; the other type is not provided with a permanent bottom. The bottom opening of this latter type is closed with a temporary wooden bottom which is removed after the caisson is placed on the foundation. The stone used to fill the compartments combines with the foundation material to provide additional resistance against horizontal movement. Typical sections of concrete caisson breakwaters are shown in figure 1-8.

(4) Pneumatic. The pneumatic breakwater is composed of a bubble screen generated by releasing compressed air from a submerged manifold. Rising bubbles induce a vertical current, which in turn produces horizontal currents away from the bubble-screen area on or near the water surface in both directions; i.e., in the direction of oncoming waves and in the opposite direction. Near bottom, the corresponding currents flow toward the bubble screen, thus completing the circulation pattern. Surface currents moving against the direction of wave propagation produce some attenuation of the waves; however, this type of breakwater can only effect a partial dissipation of the incident wave energy. It becomes more effective as the wave steepness (H/L) and the relative depth (d/L) increase (short-period waves in deep water). Figure 1-9 shows a conceptual sketch. Pneumatic breakwaters are discussed further in Chapter 7.

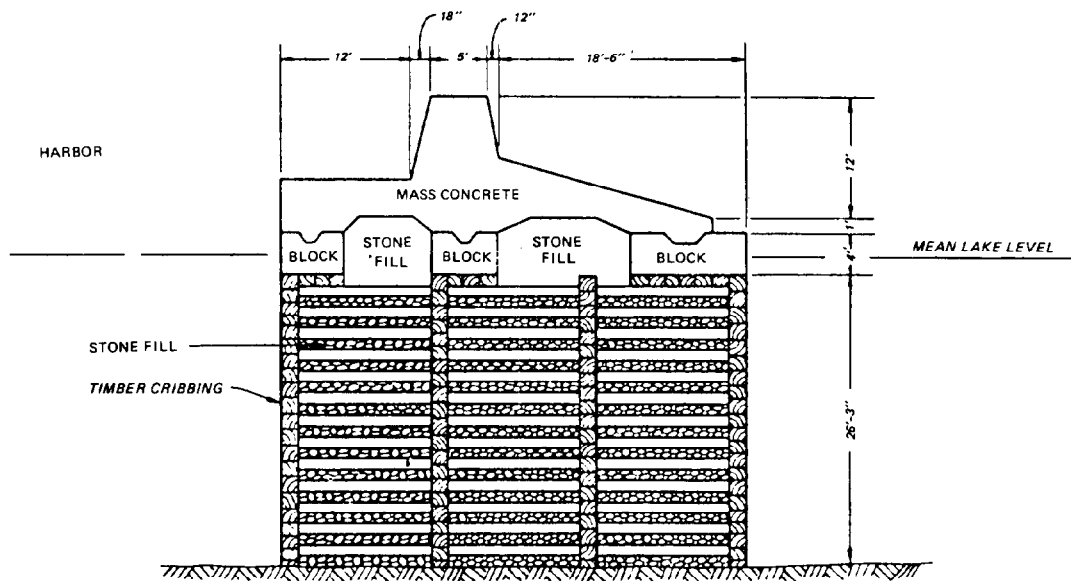
(5) Hydraulic. Hydraulic breakwaters dissipate incident wave energy by directing a current against the oncoming waves. Currents are generated by water jets from a manifold system located at or near the water surface. This



SECTION - BREAKWATER
MARQUETTE HARBOR, MICHIGAN



SECTION - BREAKWATER
TWO HARBORS, MINNESOTA



BREAKWATER AT HARBOR BEACH, MICHIGAN

Figure 1-6. Examples of timber crib breakwaters constructed on the Great Lakes

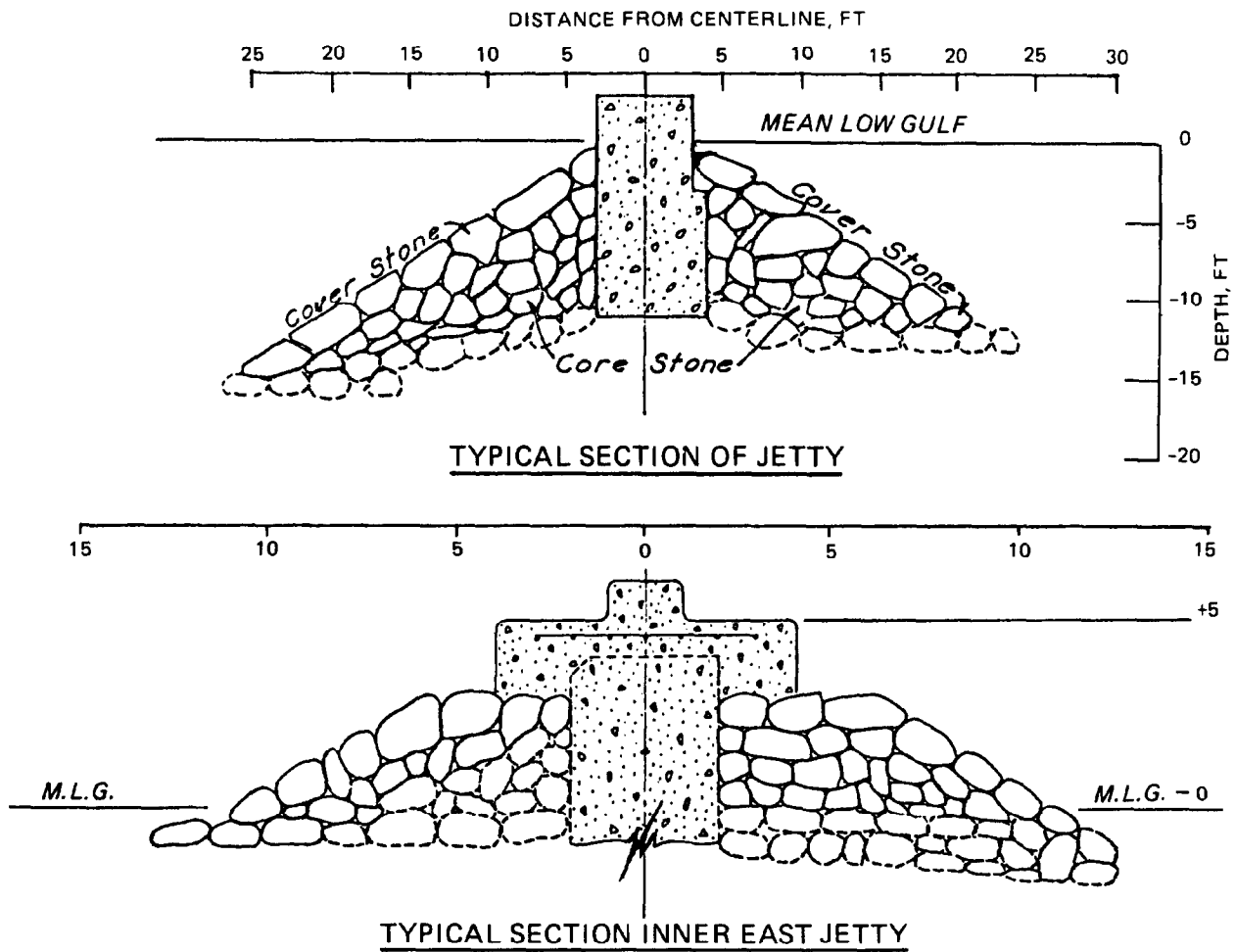
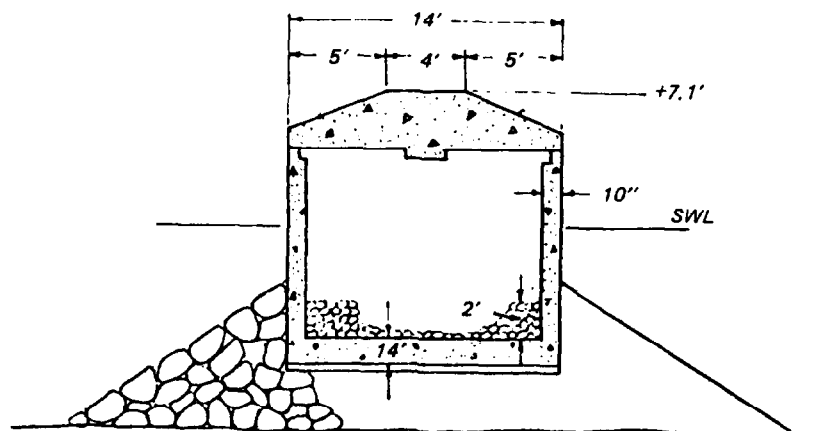
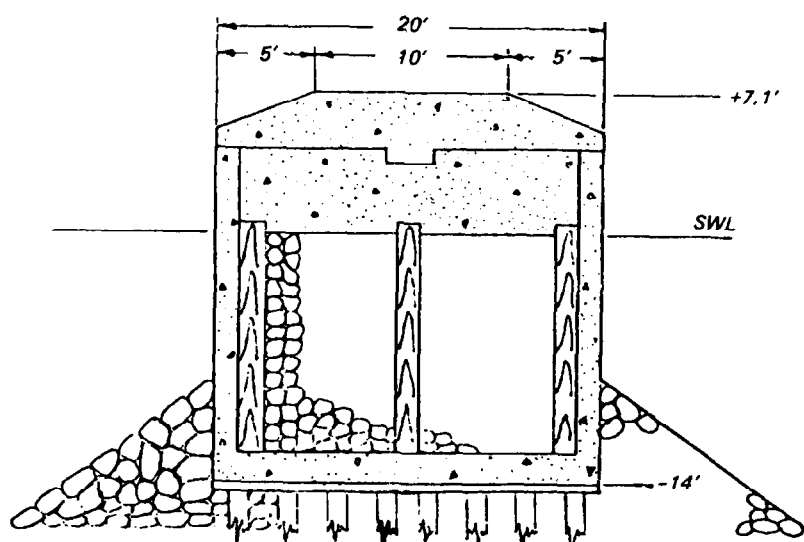


Figure 1-7. Composite jetty sections constructed at South and Southwest Passes, Mississippi River Outlets

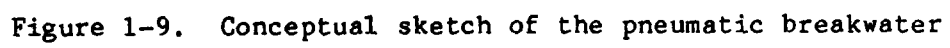


TYPICAL SECTION - NORTH AND SOUTH BREAKWATER
MILWAUKIE HARBOR WISCONSIN



TYPICAL SECTION - NORTH BREAKWATER
SHEBOYGAN HARBOR, WISCONSIN

Figure 1-8. Examples of concrete caisson breakwaters constructed on the Great Lakes



method of achieving wave-height reduction by the use of countercurrents is the same for pneumatic and hydraulic breakwaters. Thus, the practical limitations are the same; i.e., the range of wave conditions for which adequate wave reduction can be achieved is limited to short-period waves in relatively deep water. A conceptual sketch is shown in figure 1-10. Hydraulic breakwaters are discussed further in Chapter 7. It should be noted that neither pneumatic nor hydraulic breakwaters have been field proven.

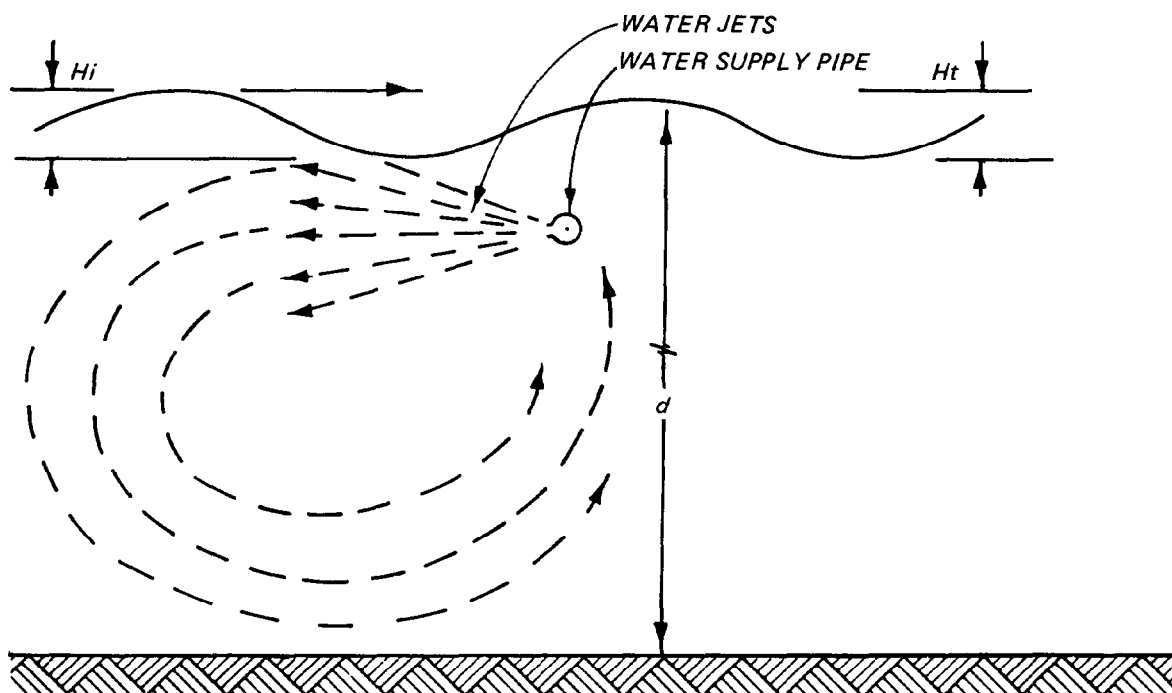


Figure 1-10. Conceptual sketch of the hydraulic breakwater

(6) Sloping float. The sloping float breakwater (SFB) is a wave barrier that consists of a row of flat slabs or panels. The weight distribution of these slabs or panels is such that each panel rests with one end above the water surface and the other end on or near the bottom. Various types of construction are possible; however, compartmentalized steel or concrete barges are the most practical. The height of protrusion of the bow above the water surface (i.e., the freeboard) is controlled by flooding a selected number of pontoons. Barge modules are sited so the bow faces the primary direction of wave attack, and wave attenuation is achieved by reflection and turbulent dissipation. Figure 1-11 shows a conceptual sketch. SFB's are discussed further in Chapter 7.

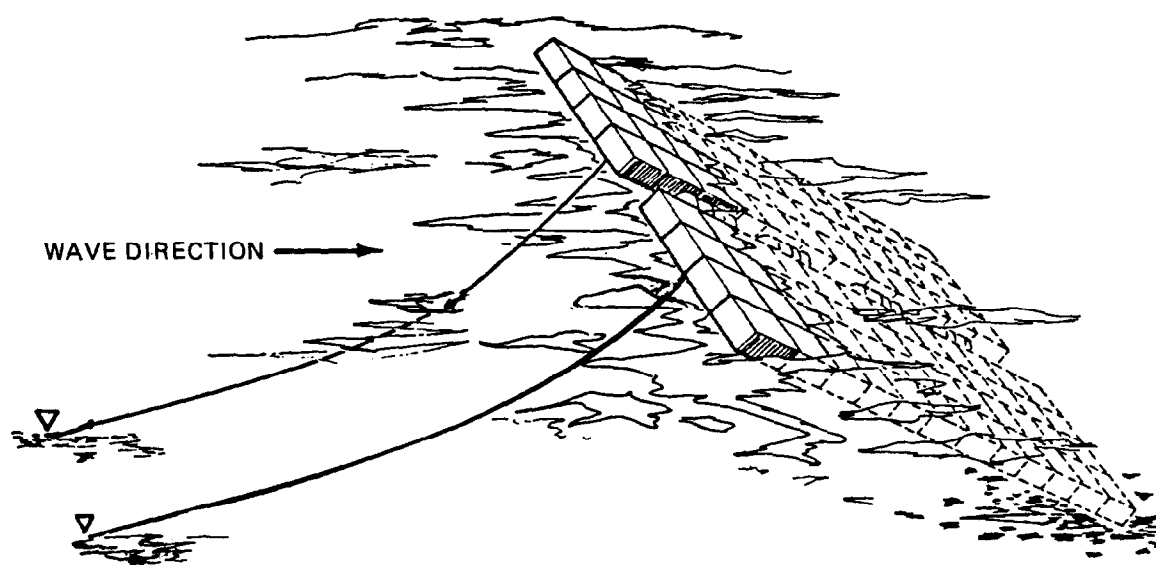


Figure 1-11. Conceptual sketch of the SFB